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DEVELOPMENT OF DETONATOR DELAY T-91 FOR ARMY 30MM FUZE (U)

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U. S. NAVAL ORDNANCE LABORATORY

WHITE OAK, MARYLAND

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DEVELOPMENT OF DETONATOR DELAY T-91 FOR ARMY 30 MM FUZE

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ABSTRACT; Development of a delay detonator system to be housed in a 1/2-inch ball rotor for use in an Army 30 mm projectile fuze is described. The design consists of two components, a stab primer, 0.160-inch OD by 0.086-inch long and a delay detonator, 0.160-inch OD by 0.351-inch long. The delay detonator is contained in a modified Mk 10 Mod 0 Delay Element case and is made up of an igniter, a delay column and an encapsulated base charge. A field test against a target of 1/4-inch aluminum indicates adequate output, a probable no delay frequency of about 4 percent, and a combined probable long delay and dud frequency of about 25 percent. The dud and long delay deficiency is attributed to delay case rupture. Suggestions are made for an improved design having greater strength.

Explosions Research Department
U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

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The work involved for this report was undertaken at the request of Picatinny Arsenal to assist in the design of a delay detonator for an Army 30 mm projectile fuze. This report is a summary of the work performed by the Explosion Dynamics Division of the Explosions Research Department to meet this commitment. The work was done under Task 182-816/64011/90040, Aircraft Machine Gun Ammunition Detonators. This task was an extension of a parallel Navy project that was terminated in 1955. The earlier Navy task was NOL-A-2b-327-1-55, High Performance Aircraft Machine Gun Fuzes, Problem 10, New Fuze for 30 mm Aircraft Ammunition.

Effort for subject report was concluded by Picatinny Arsenal before ultimate objectives were achieved. This derived from lack of funds and the fact that interest in improving the 30 mm gun system waned in general with the advent of a change in emphasis from conventional systems to missiles.

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Acknowledgement is made for the able assistance provided by John F. Davis who designed the loading tools and test fixtures, and supervised the loading and testing involved in the laboratory experimental work.

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INTRODUCTION AND BACKGROUND

In air warfare where fighter planes are attacking other aircraft an HE projectile burst inside a target aircraft does appreciably more damage than a skin burst - thus there is a requirement for a delay detonator. This report is a summary of the work performed under Army support for the development of a delay detonator for use in an Army 30 mm Projectile Fuze. It represents a continuation of a cancelled, parallel Navy project.

Preliminary Consideration for the Navy Design

The problem of the Navy supported development had been to design a delay detonator system with a delay of about 500 microseconds which is equivalent to a target delay (burst behind target) of about 15 inches. The delay detonator system was to be contained in a 1/2-inch ball rotor. Packaging the delay system in this rotor limits the available length for the entire system to 0.438 inch. Shelf items this small and of the required delay range entailing relatively minor modification for immediate application were non-existent. However, at this time an item offering possibilities had been brought through the development and production phases by the Naval Ordnance Test Station. This item was the Mk 10 Mod 0 Delay Element used in the Mk 176 Mod 1 Fuze. The rotor of this fuze contains the delay system which consists of a stab primer, a delay element, and a flash detonator. A sketch of the rotor containing the NOTS delay system is shown in Figure 1. This system was used as a starting point for the NOL effort. The problem was then one of miniaturization. Figure 1 also shows the miniaturized system arrived at in this Navy supported program. It was a two component system consisting of a stab primer and a delay detonator. The delay detonator was made up with a NOTS Mk 10 Mod 0 Delay Element Case, ignition assembly, shortened delay column, and an NOL detonator packaged in a 0.005-inch thick aluminum cup which is reconsolidated against the delay column in assembly.

The Delay Mixes

A comparison of delay times resulting from the use of different igniter and delay mixes in the Navy supported program indicated that, of the materials tested, the composition

of the igniter mix had the greatest influence on delay time. This is shown in Table I in which the variables of the Figure 1 design were igniter and delay mixes tested at various times and for various reasons but not in connection with a definitive study of delay time vs igniter and delay mix composition. Mixes 1 and 3 had been worked out by NOTS. Mix 2 is a modification of Mix 1 and was designed to reduce the delay time of Mix 1. Mix 3 is significantly better than Mix 1 as regards stability. After 35 days of the Mil-Std-304 Test, Temperature and Humidity Cycling, Mix 3 showed a shift in the mean delay time from 285 to 433 microseconds and no failures due to test conditions. Although this is a 52 percent change it is rather remarkable for a pyrotechnic delay in an unsealed device. The 433 microseconds is equivalent to about a 14-inch target delay in a field round. After only 14 days of the Mil-Std-304 Test, Mix 1 showed a lengthening of the mean delay time by a factor of 2-1/2 and 4/20 failures.

Analysis of Bench Test Delay Failures

Consideration of a large body of bench test data for the NOL developed delay systems indicated a persistent frequency of 10 to 15 percent for the combined total of duds and long delay times. Long delays were of the order of 1000 to 5000 microseconds when the mean delay was about 300 microseconds.

The duds and long delays were attributed to the fact that the solid end of the delay case in contact with the stab primer ruptured in these instances. Normally, the bench test of the delay system was a destructive test. The item blew up and left no evidence that would be helpful in the elucidation of the cause of long delays. When a bench test involved a failure, however, something was left to examine. Almost invariably, when a failure occurred, the solid end of the delay case was found to be ruptured in some fashion. In some cases the solid end was gone completely, in others a hole appeared in the center, but in most instances about a half of the top was split away from the wall. Break down of the delay case indicated that the igniter was either burned out, blown out, or a combination of both. Occasionally, the delay increment showed evidence of just starting to burn, but practically never did the delay increment burn through to the lead azide.

This information, together with the established fact that leaks in an obturated delay system result in long delay times, led to the conclusion that long delays and duds in which the case ruptured were of the same mechanism. Thus it was deduced that in a long delay the case ruptured and caused a reduction in the pressure on the burning front, thereby lengthening the delay time without interruption of burning. In a failure the case also ruptured, but perhaps more violently so as to rapidly reduce internal pressure or sweep burning igniter and delay mix out of the case. Whatever the actual mechanism, the result was a discontinuity of burning.

Field Testing of the Navy Design

Several field tests on the basic design shown in Figure 1 were conducted. In all, 67 rounds containing essentially this design were tested in the field in gun fired complete rounds. A summary of the results of these tests is shown as item 1, in Table II. No delays (instantaneous or on target fires) occurred with a frequency of 2/67. Since this condition was not encountered in bench tests, it must have resulted from target impact. Possible causes were premature lead azide initiation due to shock under impact, or premature lead azide initiation due to disruption of, and flash past the delay column. The frequency of no delay was quite low and, since this does not represent a complete tactical loss, this condition might well be accepted. The troubling aspect was that the target was very light, 1/16-inch aluminum, and on heavy plate the condition might be aggravated. At the time, this question could not be resolved as the Navy test projectile itself broke up on any target heavier than 1/16-inch aluminum.

The combined dud (2/67) and long delay (3/67) frequencies probably could not be tolerated. The duds would cause no explosive damage, neither would the long delays unless they were stopped by some heavy structure within a target aircraft. In bench tests, duds and long delays occurred and to about the same frequency. If, as previously discussed, the cause of this condition was the rupturing of the delay case, strengthening the case might offer a solution to the problem.

Of those rounds which fired, 65/67, atypical performance (relatively small bursts) was observed with a frequency of 5/65. Possible explanations were: fuze or projectile break up, poor rotor alignment resulting in low orders, or low orders inherent in the explosive train.

Terminal Status of the Navy Supported Development

The design arrived at is shown in Figure 1. Bench and field tests indicated the design had merit. There were unquestioned problems: a no delay frequency of 2/67 that might be lived with, a dud-long delay frequency of 5/67 that needed correction, and an atypical fire frequency of 5/65 that required an explanation and a solution. Based on light plate testing, it might be said at this stage that the design was about a 70 percent item. Heavy plate testing might necessitate a more pessimistic reappraisal.

Picatinny Arsenal was also interested in the delay detonator for the 30 mm projectile fuze. Not long after the results in Table II were obtained, this interest led to further testing by the Arsenal to determine the heavy plate capabilities of the system. The people at Picatinny Arsenal felt that their test vehicle (projectile and fuze) could withstand impact against a 1/4-inch aluminum target. On three different occasions the same basic system was tested using different igniter and delay mixes to change the delay time. A summary of the Picatinny Arsenal and the NOL results are given in Table II, items 1 and 2. Out of fifty rounds (item 2) the dud frequency was 3/50, the long delay frequency was 4/50, the no delay frequency was 2/50, and the atypical fire frequency was 2/47. The results are essentially the same for all target thicknesses up to 1/4 inch. This means that no new problems developed on increasing the target thickness by a factor of four. Further clarification was also obtained about the atypical fires. Photographic observation of the tests at Picatinny Arsenal (not used in the NOL tests) indicated that the atypical fires were low orders.

Except for the sole adjustment of low order for atypical fire, the analysis of the NOL field results applied equally to the heavy plate test conducted by the Picatinny Arsenal.

THE JOINT NOL - PICATINNY ARSENAL DEVELOPMENT

Picatinny Arsenal personnel found the results tabulated above to hold much promise for a successful system. Consequently, the Arsenal undertook financial support for the continuance of the NOL development of a delay detonator for use in an Army 30 mm projectile fuze. The Laboratory was to continue along lines already established - a delay system consisting of a stab primer and a delay detonator. The Arsenal was to be responsible for the necessary field tests. At the request of the Arsenal, the components of the delay system were to be designated: Primer Stab T-117 and Detonator Delay T-91.

EXPERIMENTAL TECHNIQUES

Laboratory Delay Time Test

Delay timing of experimental delay detonators was accomplished by modifying available apparatus, the Test Set Mk 256 Mod 1 (LD 291791). This consisted of a firing chamber, a firing device, and a timing system. The modification involved was the design of a new chuck and a new test fixture to contain the delay detonator system. The actual timing unit was a Potter electronic chronograph.

Laboratory Steel Dent Output Test

In the Laboratory a measure of delay detonator output for different design developments was required. This was done by the steel block dent test. The steel block dent test used as a measure of output the volume of a dent in a steel plate produced by the exploding fuze component. The dent was assumed to be a cylinder, the dimensions of which were the depth of the dent and the diameter of the explosive. This is quite far from the true dent contour, but generally the same item is tested in comparative situations so that the depth of dent, measured under similar conditions gives a measure of the output. It is felt to be the most reliable output test available for fuze component comparisons.

It had been hoped to obtain output data using the assembled delay system in contact with a steel block. However, the resulting dent was frequently so loaded up with the disc and fragments of the crimp that meaningful measurement was impossible. Efforts at improvement by interposition of thin steel discs between the detonator and block were unsuccessful. As a compromise, the test assembly shown in Figure 2 was designed in which the base charge alone was tested. A steel sleeve was used to simulate the confinement obtained in the assembled delay case. It was felt that this test set up would be helpful in comparative studies, but it was realized that results accumulated in this fashion would have to be correlated to results obtained from end item geometries and assembled explosive components to be definitive. End item conditions were approached as closely as cost considerations would permit by the design of a simulated fuze test assembly which would yield bench output data through the booster. This design is shown in Figure 3. It can be compared to a schematic sketch of the actual fuze train as shown in Figure 4.

The Field Test Arrangements

The final testing of the delay detonator was done in the field by firing complete rounds. The rounds were identified by number, but they do not necessarily appear sequentially in tabulated results. The field test provided a measure of the target delay and a measure of the order of explosive burst.

Photographic Recording. A high-speed 16 mm motion picture camera operating at 6000 to 8000 frames/second and using an Army field searchlight for illumination recorded the tests. This speed is ample to show progression of projectile, impact, first burst, and growth of the explosion. In use, the camera saw a field which included about a foot in front of the target, the target, and about 5 to 8 feet of the distance determining reference board. The reference board has lines at 6 inch intervals with the target at the zero reference line. Thus the target delay, when in the camera field, was accurately fixed by first appearance of explosion on this background "ruler". High speed film was also very helpful in determining the explosive order. However, this estimate at the present state of the art is not as definitive as the target delay number.

Visual Observation. In the case of long delays, the explosive event occurred beyond the camera field and would be seen as a dud by the camera. In those instances, judgment of performance depended on visual observation and the use of witness screens. Visual observation by the unaided eye provided a guess as to location of burst, color and amount of smoke, and meaning of a disturbance on the ground. All of which was unreliable, but for delays beyond ten feet it was the only estimate available.

Witness Screens. The more meaningful visual aid, the witness screen, was a 4 by 6 feet sheet of ordinary box cardboard placed on the ground behind the target and approximately centered with the flight path of the projectile. The pattern of holes made by the case-fragments of an exploded projectile was some guide to the target-delay and the order of explosion. A typical high order burst left a flat arc of peppered holes at right angles to the long axis of the witness screen. The distance of this peppered band from the target was some measure of the delay. A typical low order burst showed up on the witness screen as relatively large longitudinal tears with no regularity in pattern. The delay in this instance was found some place between the first hole and the target. Instances occurred in which low orders fragmented beyond the witness screen and were designated duds on this basis, but were actually found to be low orders and ascribed a delay on the basis of the high speed film record. The witness screen offered an on-the-spot estimate of the delay and order of a test round. This record could be made permanent by means of an inexpensive snapshot.

Target Hole Size. The target hole size provided additional information in determining the delay distance for delays close to the target. One caliber or 1-1/4-inch holes were made by inert rounds and live rounds passing entirely through the target. A 5- to 8-inch target hole was an obvious instantaneous fire or no delay, as explosion occurred before target penetration. However, it is possible for a round to swell on passing through the target making a hole larger than one caliber, but firing entirely behind the target. Criteria for determining whether a round fired with a delay or no delay on the basis of target hole size alone have not been established. Nonetheless, this information is a helpful adjunct to photographic and witness screen data.

THE PRELIMINARY FIELD TESTS AND ANALYSIS OF RESULTS

At the outset it was considered desirable by both NOL and Picatinny Arsenal that another field test of the detonator system be conducted to amplify the existing data and give a firm definition of the problem areas. This was done in a test of fifty rounds fired against 1/4-inch aluminum plate. A sketch of the delay system is shown in Figure 5 and details of the delay assembly are contained in Table III, rounds 1 - 50. The results of the test were obtained by high speed motion pictures and by visual observation. The test results are shown in Table IV.

These results indicated that the delay distance determined by visual and witness screen observations in all cases was appreciably larger than the more accurate high speed film record for the same round. It will be noted further that this difference between the visual and photo value was greater for the low order rounds than for the high order rounds. The means of delay distances follow:

	Photographic Observation (inches)	Witness Screen and Visual Observation (inches)
Low Order	9.6	55.7
High Order	5.6	13.0

Photographically, evidence of the round burst was detected as it occurred in the air. Visually, detection was by the fragmentation pattern on the witness screen lying on the ground some 18 inches below the round. In the case of low orders, the downward acceleration of the fragments imparted by the explosion was relatively low and they did not strike the witness screen until they had travelled a fair distance from the burst - on the average about 46 inches horizontally. A delay estimate in this instance appeared as a long delay when judged by the witness screen alone. In the case of high orders, the downward acceleration imparted was much greater and the fragments reached the witness screen in a much shorter time and distance - the difference between the photo value and witness screen value being about 7 inches on the average.

Photographic observations showed a mean delay distance for high orders of 5.6 inches and for low orders, 9.6 inches. This difference can probably be accounted for in the difference in build-up time for projectile case rupture.

As shown in Table II, aside from the frequency of low orders, the results of the field test were essentially the same as in previous tests and the former analysis applies equally here. There was a startling difference in the low order frequency, an increase from 2/47 to 18/46, of presumably the same system tested in identical fashion.

A careful check was made of loading and assembly records and explosives used in preparing the delay detonator. Samples of the delay detonator from the same batch used in the field and set aside for this purpose were tested on the bench. Some work was done on the variation of the lead azide and PETN ratios and loading pressures. The result of all this was to pose a question as to the validity of the output criteria used in the past. However, nothing done would satisfactorily account for the large difference in the low order frequency in the successive field tests.

A review of field test conditions indicated that in the previous tests the gun-to-target distance was 300 feet and only 100 feet in the last test. The gun-target distance is an important factor in rotor arming as some question exists as to whether the minimum arming distance had been definitively established for the Army fuze. Using a small detonator, the explosive train might function with high reliability under conditions of perfect rotor alignment, but with some misalignment misfires or a high frequency of low orders might occur with the same detonator. The arming problem is considered because it would be well to know with high confidence that results of field tests are due to the delay system alone and not in some unknown degree to deficiencies inherent in the test vehicle. Although it might not be possible to fully explore this question, it was felt advisable to at least run future tests at a gun-to-target distance of 300 feet.

The problem areas were thus defined:

An average no delay frequency of about 4 percent.

An average low order frequency of about 40 percent.

An average dud and long delay frequency combined of about 13 percent.

These problem areas will be considered in the order mentioned. Reference will be made to results of field tests as relevant to specific design changes arising during the course of development.

DESIGN DEVELOPMENTS

The No Delay Problem

As summarized in Table II, the no delay frequency of the starting design of the delay detonator was about 4 percent for all field tests. This no delay condition was attributed to target impact as it did not occur in bench tests. Because of target impact it was reasoned that the lead azide part of the detonator was initiated directly, thus by-passing the delay. Possibly this happened because of shock action on the lead azide or because of immediate flash-through by the igniter as a result of delay fissures or flexing of the case wall. Whatever the mechanism, the resulting 4 percent no delay frequency was relatively low and might readily be lived with as it was not a complete tactical loss in any sense. For this reason, and because of the need to husband available effort for the more serious problems, it was elected to accept this no delay frequency. Consequently, no direct attempt was made to reduce this frequency below the 4 percent value inherent in the starting design. Changes in design arising from attempts to correct other deficiencies did not increase the no delay frequency in the design finally arrived at. The no delay frequency of the terminal design of the delay detonator was therefore maintained within the 4 percent objective.

The Low Order Problem

Although the large difference in the low order frequency in two successive tests (4 to 39 percent) could not be explained satisfactorily on the basis of detonator output alone, it was apparent that the output of the detonator, even in the case of the 4 percent frequency, was marginal and required increasing. Because of the length limitation imposed by the need to fit the delay system in a 1/2-inch ball rotor, only two directions were available for increased output: better explosives in the existing system, or a modified system providing for an increase in explosive diameter.

Improved Output by Better Explosives. Other experimental work at NOL indicated that a detonator made up of silver azide and HMX had promise, particularly in tight space situations. Exploratory work was undertaken toward establishing increased output of the present system through the use of these explosives in the existing cup. The steel block test was used as a measure of output in the evaluation of this work. Data obtained for various base charge assemblies using the output test assembly shown in Figure 2 are compiled in Table V. Items 1 through 7 were improvised materials. For items 8 through 17, the test was standardized by using a fixed ignition charge weight in the initiating plug and a cold rolled steel sleeve of 0.060-inch wall thickness. Items 1 and 12 have the base charge used in the field tests discussed previously; the item it was hoped could be improved with better explosives.

Testing by the method shown in Figure 2 established that:

> As the ratio of PVA lead azide to PETN base charge was decreased the dent was increased, although the change was relatively small. A 5 percent increase in dent was achieved by increasing the PETN base charge length from the standard 0.122-inch to 0.179-inch and decreasing the lead azide charge length from the standard 0.114-inch to 0.057-inch. An increase in loading pressure from the standard 10,000 psi to 20,000 psi increased the dent about 10 percent for PVA lead azide - PETN systems. Increased confinement going from test sleeves with 0.020-inch wall thickness to test sleeves with 0.060-inch wall thickness increases the dent 10 to 12 percent.
>
> A change from PVA lead azide - PETN systems to silver azide - HMX systems increases the dent 10 to 15 percent.

The base charge assemblies were also tested in the simulated fuze mock up shown in Figure 3. The test results are shown in Table VI. Item 1 is the starting design and items 3, 4, and 5 are pertinent here. These tests established that:

> The silver azide - HMX base charge assembly fired high order when tested alone, but failed to initiate the booster high order when reconsolidated in the delay detonator assembly and tested in the fuze mock up.
>
> Efforts at improvement by adjusting the charge weight ratio using the original sample of silver azide were unsuccessful.
>
> The same adjustment with a new sample of silver azide resulted in 10/10 high orders and an improvement in the ability of the base charge to initiate the booster to the extent of a 10 percent increase in dent value over the starting design.
>
> Difficulties existed with batch to batch reproducibility in the laboratory scale preparation of silver azide.

Although plate dents could be increased by a change in the explosives, further work was stopped because results of a parallel study with increased diameter base charges were proving so encouraging.

Improved Output by Explosive Diameter Increase. Designs of delay detonators incorporating an increase in explosive diameter were brought through the bench study phase to final field testing.

Pre-Design Considerations. One method of obtaining an increase in explosive diameter is to increase the delay case diameter overall. The OD of the system to be improved, Figure 5, is 0.160-inch, the ID is 0.120-inch, and the diameter of the explosive in the encapsulated detonator is 0.110-inch. The diameter of the entire system could be practically increased up to 0.190 inch, thereby increasing the base charge diameter and quantity of explosive proportionately within this range. Factors to be considered are:

A stab primer of larger diameter would be required, and involved in this would be the need of balancing primer output against ignition assembly sensitivity, keeping in mind the troublesome problem of the ruptured case.

Juggling the pyrotechnic igniter and delay might be necessary because of the attendant charge increase with diameter increase.

New primer and delay case parts, new rotors, and new tools for loading and assembly would be needed as well as additional time and money to accomplish the change-over.

A similar approach in which the OD of the delay case is enlarged but the ID of the igniter and delay end is maintained and only the detonator ID increased would resolve some of these problems, increase the cost of the case, and make necessary a check to see that the thinned wall on the detonator end did not present a new problem.

Another factor necessary to examine when considering explosive diameter increase is the matter of safety in arming. The diameter of the explosive, selected to assure adequate output for reliability, must not be so large as to jeopardize safety in the unarmed condition. With so small a system as the 1/2-inch ball rotor, the margin between high reliability and adequate safety is at best quite small.

As the pre-design review above indicates, any extensive design studies involving actual procurement of delay parts and attendant tooling would be costly beyond reason when compared to the funds available for the complete study and development. It was therefore felt that a first effort toward explosive diameter increase should be made by modifying the available case for these reasons:

This would involve reaming the ID out down to the delay or part of the delay and permit use of all parts in the old system except a new cup to contain the enlarged diameter base charge and tools for loading it.

If the thinned wall section held up, at least for bench tests, the data thus obtained might provide directly, sufficient information for ultimate design.

If required, arming safety studies might be conducted up to an ID of the thinned section of 0.136 inches which would leave about a 0.012-inch wall, probably the thinnest practicable.

If in some rounds the modified case were to withstand target impact, further information for ultimate design would be obtained from the resulting target impact data.

Bench Studies of Designs Developed. The development of designs evolved to increase output by increasing explosive diameter and using modified available delay cases are shown in Figures 6, 7, 8. Figure 5 represents the system arrived at when the NOL program was cancelled and the starting point for the Picatinny Arsenal work. Figure 7 is a design in which explosive is loaded directly into the delay case. Figures 6 and 8 show delay systems which contain the same increased diameter encapsulated base charge, but the designs differ in manner of base charge support. These systems were identical as far as bench studies were concerned.

Bench Delay Time Study. Bench delay tests were conducted to determine the effect of thinning the case wall. Possible results of thinning the case wall to about 0.012-inch are these:

Primer shock might so affect the system that igniter flash-through occurs and this would be read as an extremely short delay time.

The thin section might rupture in such a fashion as to vent the igniter and this would show up as a long delay time.

To better distinguish normal delays from the potentially possible abnormal delays mentioned, two groups, one of mean time 400 microseconds and one of mean time of 1000 microseconds were made up for systems, Figures 6, 7, and 8 and bench tested.

The 400 microsecond groups were to be used in identifying long delays, should they occur, and similarly, the 1000 microsecond groups were to point out with greater facility short delays, should they turn up. Since in all cases normal delay patterns were actually obtained, it was evident that the thin section was not a problem, in bench tests at least, and it was feasible to continue further bench work by conducting output studies.

Bench Output Study. The results of the output tests conducted as shown in Figure 2 are recorded in Table V. The directly loaded explosive design could not be treated in this fashion and therefore no results are shown for it. A result for a conventional stab detonator, designed to fill the entire rotor cavity and representing the upper output limit is also included for comparison. This test affords valuable basic output data but the meaningful information for comparative judgment is the dent value obtained from the simulated fuze test.

The set up for the simulated fuze test is shown in Figure 3. This test measures the ability of various assembled base charge designs to initiate the booster. The results are shown in Table VI. For convenient comparison, the relevant dent values are scaled to the starting design as unity and shown below:

Item	Relative Dent Scale
Starting Design	1.00
Encapsulated Base Charge Designs	1.19
Directly Loaded Explosive Design	1.27
Stab Detonator	1.24

As shown above, all three designs to improve output showed significant gains in dent value over the starting design. Since preliminary bench studies indicated improved output and no adverse effects on the delay, the more rigorous field tests and other work necessary to complete the evaluation for the three designs were performed.

Directly Loaded Explosive Design. The directly loaded explosive design is shown in Figure 7, the assembly details in Table III, rounds 86 through 95, and the results of the field test in Table VII, rounds 86 through 95. Only 10 of the 20 rounds prepared for the test were fired. All ten fired high order which confirmed bench data as regards output. The frequency of no delay fires was quite high. This could be attributed to target impact effects as the delays were normal in bench tests. Two rounds showed target holes of one caliber and unequivical photo evidence of delays. Four rounds, however, showed target holes of 1-7/8 to 2-1/4 inches which, in connection with high speed photo data, suggests detonation just after target penetration. In any event the most optimistic no delay frequency is 50 percent;entirely too high for a production item.

Since the directly loaded explosive design proved so effective as regards output, it was felt that some effort should be made to eliminate the no delay condition. Therefore, this design was modified to contain both one and two 0.004-inch thick polyethylene washers between the delay and azide components. It was thought that the washers might act as a cushion and wall seal and thereby prevent either igniter flash-through or azide initiation by crush action. The design is not shown but is identical to the Figure 7 design with the exception of the modification mentioned. Assembly details are shown in Table III, rounds 141 through 160. Bench tests of this modified design demonstrated high order fires and normal delay times. The field test results of this design are contained in Table VIII. Interpretation of field results was by visual methods alone, as high speed photography was not used in this test. However, in this instance the visual technique was adequate as regards test objectives. All rounds that fired were unquestioned high orders. Nonetheless the modified design showed no improvement in the no delay frequency, being 5/10 for the case of one washer and 5/8 for the case of two washers.

The primary cause of the high frequency of no delays might be the thinned delay case wall surrounding the detonator. It might also be the direct contact of delay

column and lead azide. In the latter case the no delay would be evident no matter what the wall thickness. This no delay condition precluded the use of directly loaded explosives in end item design. However, experimentation with this design was fruitful in terms of immediate objectives in that adequate output was demonstrated in the field. No further work was done with this design.

Encapsulated Base Charge Designs. The other approach to increased output by increasing explosive diameter was that of the encapsulated base charge. The start in this direction is shown in Figure 6. In this design the use of available parts and tools was possible. The case was reamed to 0.136-inch ID and the ignition and delay systems were the same as in the original design.

Potential problems previously discussed and associated with the thinned case wall of course apply here. In addition, there is another potential problem because of the base charge support against a metal shoulder. Crush action might initiate the azide directly. Unavoidable small amounts of delay mix caught between the base charge and the shoulder might also ignite directly on impact and result in no delays. Since the design information would prove valuable in any case, the Figure 6 design was tested in the field. The assembly details are shown in Table III, rounds 76 through 85, and the field test results are contained in Table IX, rounds 76 through 85.

Despite adverse test conditions because of very bad weather, sufficient information was obtained to indicate an improvement in output, 7/8 unquestioned high orders and 1/8 probable high order. The no delay frequency, however, was quite high, 4/8, and required correction. It seemed reasonable to assume that the cause of the high frequency of no delay was to be found at the metal shoulder support. The design was therefore modified as shown in Figure 8. Here the base charge was supported by the delay mix. Though complicated by a thinned wall section, it was hoped that the delay column would act as a cushion much as in the original design in which the no delay frequency was only about 4 percent. The assembly details are contained in Table III, rounds 106 through 125.

The results of the field test are found in Table VII, rounds 106 through 125. Since two rounds missed the target, only 18 rounds were available for output data. Of these, 14 rounds were unquestioned high orders on the basis of photo data confirmed by witness screen data. In the case of 4 rounds, the sole criterion was the fragmentation pattern on the ground as the delays were long. However, in these instances the patterns were so distinct and so typical that there was no question but that they were high order. Thus the high order frequency was 18/18 indicating that the Figure 8 design was a solution to the low order problem.

Further field testing of the Figure 8 design was terminated at this point because the money available at NOL was expended and the Arsenal did not elect to supply additional funds for continuing the project. Since this design proved to be the best developed during the program, an overall estimate of accomplishment must be based solely on the output and other information obtained from this one twenty-trial field test.

ANALYSIS OF THE DESIGN DEVELOPMENTS

Terminal Status, Optimum Design

The low order frequency as indicated was 0/18, demonstrating adequate output. Other information obtained from the results of this field test as shown in Table VII, rounds 106 through 125, concerns the no delay, long delay, and delay in range frequencies.

The no delay frequency was obscured somewhat by questionable rounds.

Two rounds missed the target. In one case the wind blew a witness screen in front of the target just as the round was fired, making it impossible to determine if the round initiated on the witness screen or on the aluminum target. This round was disregarded.

Celotex targets were used for two rounds. Although no instantaneous or no delay fires occurred, celotex did not represent the most severe target impact conditions and therefore these rounds were disregarded.

The target holes for two rounds were slightly larger than one caliber but these rounds definitely passed through the target before firing and were therefore included in the no delay count.

The no delay frequency was therefore 0/15. The no delay frequency in the starting design was 6/167 or about 4 percent. It is considered that the no delay frequency in the Figure 8 design might also run about 4 percent on the average (although test results show 0/15) as the designs are essentially identical relative to those factors effecting the no delay conditions.

The long delay frequency is somewhat in doubt because the delays were long in the case of two rounds fired successively against celotex targets. It was discovered that soft targets have some lengthening effect on delay time. As shown in the appendix, a target delay of about seven inches could be attributed to target alone in the case of stab detonators fired against relatively hard cardboard. More testing would be required to determine the precise effect of celotex targets on delay time. The long delay frequency of the field test under discussion is 3/15 or 20 percent or 5/17 or 30 percent depending on the allocation of the celotex rounds. The mean frequency in field tests for a large sampling of the starting design was 21/167 or about 13 percent. It is apparent that the terminal design has appreciably increased the frequency of long delays.

The delay in range frequency for this test was between 70 and 80 percent (depending on interpretation of results with celotex targets). These results show no improvement over the starting design in which the frequency is 140/167 or 84 percent. However, it is believed that simple design changes could materially improve the performance of the terminal design as described below.

Changes Required to Improve the Design.

The serious deficiency of the present design appears to be in the frequency of long delays. This can be attributed to a ruptured case problem either at the anvil end of the delay case or at the thinned wall region of the case. The former weak region has existed throughout the development of the delay detonator, the latter was probably introduced when the base charge diameter was increased to improve output. The

anvil end can be strengthened by increasing the case thickness at the anvil end. It is believed that this can be done without adversely affecting initiation of the delay detonator. The body could be strengthened by increasing the thickness of the wall without a corresponding decrease in the base charge diameter since there is room in the rotor to increase the present 0.160-inch OD system up to a practicable limit of 0.190 inches. A length loss would accompany a thickness increase at the anvil end. If necessary, this could be taken care of by balancing wall thickness for strength against explosive diameter for output. It is felt that sufficient space is available to do this successfully.

It is to be noted that an attempt was made early in the development program to achieve increased case strength through the use of drawn stainless steel cups. It was hoped that the drawing process would work harden the material and eliminate the weak points introduced by a machining process. It developed that the technology required to produce such cups was not readily available and could not be procured within the scope of the program.

Attempts were also made to eliminate case rupture by modification of the ignition system. Two series of tests were run to determine the effects on the case rupture frequency of varying such things as anvil-washer hole relationship, type of mix, length of igniter, case wall thickness, and charge weight of the stab primer. It was felt that these ignition assembly design studies might provide a clue as to how the case rupture frequency might be reduced by internal design alone. A summary of the first study is contained in Table X. These tests showed no conclusive evidence of any relationship in the parameters that would tend toward diminishing the ruptured case frequency by igniter design alone.

In the second study the only variable was washer design. The results of the tests and descriptions of the washer designs are shown in Table XI. Here again it was necessary to conclude that no success was encountered in terms of test objectives. These studies impelled the conclusion that the ruptured case problem was one of delay case strength and that the most fruitful approach to solution was that of increasing the strength of the delay case.

SUMMARY AND CONCLUSIONS

The Laboratory undertook to develop for Picatinny Arsenal a delay detonator to be housed in a 1/2-inch ball rotor for use in an Army 30 mm projectile fuze. The requirement was a target delay of 0 to 15 inches for target material of 1/4-inch aluminum. The work involved represented a continuation of a cancelled Navy project. The starting point for the Army program was the terminal Navy design. A field test of this design revealed the following problem areas: a no delay frequency of about 4 percent, a low order frequency of about 40 percent, and taken together a dud and long delay frequency of about 13 percent.

The no delay condition was associated with target impact as it was not evident in bench tests. Possible reasons for the no delay occurrence were direct initiation of the lead azide by shock or direct azide initiation by igniter flash through because of fissures in the delay mix or flexing of the case wall. No work was done toward improvement because the frequency was low, tactically the condition might be lived with, and because of the need to solve the more serious problems.

The attempt to reduce the low order frequency was made by efforts to increase the output of the delay detonator. Since the length of the delay detonator system was fixed because of the necessity of fitting it into a 1/2-inch ball rotor, only two directions were open for increasing the output: better explosives in the existing system, or a modified system permitting an increased quantity of explosives by increased diameter.

Bench tests of the starting design, modified to contain a silver azide-HMX base charge resulted in a significant gain in output for the new explosives, a 10 percent increase in the dent value. However, because of poor batch to batch reproducibility of the silver azide, and because of encouraging results with larger diameter base charges, further efforts in this direction were abandoned.

To keep costs within the limits of the funds available in the program, all work for the increased explosive diameter approach was done by modifying available Mk 10-0 Delay Element cases. The evolution of the design to improve output by explosive diameter increase was: a design in which the explosive was loaded directly into the delay case (Figure 7); a design

involving an encapsulated base charge partially supported on a metal shoulder (Figure 6); and the terminal design, identical to the latter except support was entirely by the delay column (Figure 8). Preliminary bench tests indicated a gain in output and normal delay patterns for all three.

A field test of the directly loaded explosive design demonstrated adequate output but a 50 percent frequency of no delay. The no delay condition was a problem of target impact forces as it did not show up in bench tests. An effort at improvement by use of polyethylene washers between the delay mix and lead azide increments was unsuccessful.

The encapsulated base charge design, in which the base charge was partially supported by a metal shoulder, when tested in the field resulted in acceptable output but about 50 percent no delay. The high no delay frequency was attributed to target impact forces operating at the base charge and partial metal shoulder support. No further work was done with this design as it was felt that complete support of the base charge by the delay mix might act as a cushion and correct the condition.

A field test of the encapsulated base charge design incorporating the idea of delay column support demonstrated adequate output and a no delay frequency of 0/17. Insofar as conclusions can be drawn from 17 trial data, it would appear that this encapsulated base charge design was a solution to the low order problem.

The dud and long delay frequency in the starting design was about the same in both bench and field tests, indicating that target impact forces were not involved. Also when failures occurred in bench tests, the solid end of the delay case was invariably ruptured. These facts led to the conclusion that duds and long delays were of the same mechanism and were caused by the rupturing of the delay case. It was felt that an early effort should be made to obtain delay cases of increased strength regardless of what information might be developed from intended igniter design studies. This was done but unsuccessfully as the technical problems involved in drawing heavy walled delay cases proved to be beyond the scope of the program. Subsequent studies of the ignition system designed to reduce the ruptured case frequency by internal design alone were also unsuccessful. It was finally concluded that for the starting design the ruptured case problem was a matter of delay case strength and the most fruitful approach to solution was that of increasing the delay case strength at the solid end.

The long delay frequency of what proved to be the terminal design in the only field test of this system is in some doubt because of the small sample size and questions about two rounds fired against celotex targets. However, lacking more data, judgment must be made on the basis of the sole 20 trial field test. The long delay frequency was about 25 percent as opposed to 13 percent in the starting design. It was concluded that the starting design frequency was also in evidence here and that the increase shown was probably due to deficiencies arising from the thinned wall section in the modified design.

Design information gained from work with the modified Mk 10 Delay Element cases indicated directions to be taken for an improved design. Weakness of the delay case at the anvil end and at the thinned wall section appears to account for the major deficiency, the high long-delay frequency. Added strength might be accomplished at these points by increasing metal thickness. The OD of the case could be increased to a practicable limit of 0.190 inch. It is felt that this would provide enough space to increase the wall thickness or the explosive diameter or both, as required.

In conclusion, the terminal design (Figure 8) proved to be the best developed during the program. The no delay frequency probably was about 4 percent, the same as in the starting design. The long delay frequency was about 25 percent, an increase over that in the starting design. The principal deficiency of the terminal design was the high long delay frequency. It is felt that this condition might be improved by increasing the metal thickness at the anvil end and at the thinned section of the delay case.

Table I

DELAY DETONATOR DELAY TIME vs
IGNITER MIX COMPOSITION

Mix #	Igniter Mix		Delay Mix		Delay Time (microseconds)
1	Zirconium Hydride	29%	Zirconium Hydride	30%	850-1100
	Lead Peroxide	66	Lead Peroxide	70	
	Tetracene	5			
2	Zirconium Hydride	27			
	Lead Peroxide	63	Zirconium Hydride	30	550-750
	Tetracene	5	Lead Peroxide	70	
	Basic Lead Styphnate	5			
3	Zirconium	26	Zirconium-Nickel	35	275-350
	Lead Peroxide	71	Alloy 30/70		
	Tetracene	3	Lead Peroxide	65	

Table II

DELAY DETONATORS

SUMMARY OF NAVY AND PRELIMINARY ARMY FIELD TEST RESULTS

Item #	Total Rounds	Dud	Long Delay	No Delay	Delay in Range	Atypical Fire or Low Order
1	67	2	3	2	60	5 (5/65 = 8%)
2	50	3	4	2	41	2 (2/47 = 4%)
3	50	4	5	2	39	18 (18/46 = 39%)
TOTALS	167	9	12	6	140	

Essentially the same delay detonator was used in all tests. It is shown in Figure 5.

Item 1: Navy Test, Navy System
Round Velocity 2900 ft/sec.
Gun - Target 300 ft.
Obliquity 0°
Target 1/16-inch aluminum (24 ST)

Item 2: Army Test, Navy System
Round Velocity 2750 ft/sec.
Gun - Target 300 ft.
Obliquity 0°
Target 1/8-inch aluminmm (24 ST), 10 rounds
1/4-inch aluminum (24 ST), 40 rounds

Item 3: Detonator, Delay T-91; Rounds 1-50
Round Velocity 2750 ft/sec.
Gun - Target 100 ft.
Obliquity 0°
Target 1/4-inch aluminum (24 ST)

Table III

ASSEMBLY DETAILS OF THE VARIOUS DELAY DETONATOR DESIGNS TESTED IN THE FIELD IN GUN FIRED COMPLETE ROUNDS

Test Rounds 1 - 50
Army Starting Design, Navy Terminal Design

See Figure 5.

Stab Primer

Navy: XT65B, LD479575
Army: T-117
Complete details shown in LD indicated. Since this primer was used in all tests, this information will not be repeated for subsequent rounds. For reference here, pertinent details follow:
25 mg, NOL No. 130 Priming Mix; 30,000 psi; 0"028 length
20 mg, Lead Azide; 15,000 psi; 0"026 length
Finished: OD - 0"160; length - 0"086

Delay Detonator

Navy: XS45B, LD479616
Army: T-91 (Not necessarily this particular design but the Army designation to apply to systems developed in the course of the program.)
Complete details shown in LD479616
For reference here, pertinent details follow:

Ignition Assembly

Zirconium 26%
Lead Peroxide 71%
Tetracene 3%
23 mg; 10,000 psi
Finished: OD - 0"119; length - 0"060 (0"055 after reconsolidation)
Reconsolidate ignition assembly at 20,000 psi
Inert parts as per LD 479616

(Table III continued on page 27)

Table III (Continued)

Delay Mix

Zirconium Hydride	30%
Lead Peroxide	70%
29 mg, 10,000 psi,	0".035

Base Charge Assembly

60 mg, Polyvinyl Alcohol Lead Azide; 10,000 psi; 0".114 length
28 mg, PETN; 10,000 psi; 0".122 length
Finished: OD - 0".119; length 0".249
Reconsolidate base charge assembly at 20,000 psi
Inert parts as per LD 479616

Delay Case

As per LD 479616 (Mk 10-0 Delay Case shortened to 0".385 length)
Finished: OD - 0".160; length - 0".351

Rounds 51 - 75
To Establish Photographic Standards

See Figure 5, Delay Detonator
See Figure 4, A sketch showing relationship of explosive components of test projectile

Rounds 51 - 55:	Live through delay detonator - rest inert
Rounds 56 - 60:	Live through booster - rest inert
Rounds 61 - 65:	Live through projectile pellet - rest inert
Rounds 66 - 70:	100% live
Rounds 71 - 75:	Live primer - rest inert

Live Components
Same as in rounds 1 - 50
Inert Components
Primer, Delay Detonator, Booster and "HE" - Plaster of Paris loaded.
Projectile Pellet - An aluminum plug.

(Table III continued on page 28)

Table III (Continued)

Test Rounds 76 - 85
Increased Diameter Base Charge Assembly
Partial Support by Metal Shoulder

See Figure 6.

Ignition Assembly

Zirconium 26%
Lead Peroxide 71%
Tetracene 3%
23 mg; 10,000 psi
Finished: OD - 0".119; length - 0".060
Stop load ignition assembly to 0".055 length
Inert parts as per LD 479616

Delay Mix

Zirconium Nickel alloy 30/70 35%
Lead Peroxide 65%
29 mg; stop load to 0".032 length

Base Charge Assembly

78 mg, Polyvinyl Alcohol Lead Azide; 10,000 psi; 0".116 length
38 mg, PETN; 10,000 psi; 0".123 length
Starting Cup (aluminum): wall - 0".005; length - 0".275 + 0".005;
OD - 0".133 - 0".001; ID - 0".123 + 0".001
Paper Disc: OD - 0".120; thickness - 0".002
Finished: OD - 0".135; length - 0".249
In assembly stop load to 0".020 shrinkage

Delay Case

Inert parts and assembly as per LD 479616 except ID is reamed to 0".136
Finished:OD - 0".160; length 0".351

Test Rounds 86 - 105 (96 - 105 not fired)
Increased Diameter Base Charge
Directly Loaded Explosive

See Figure 7.

Ignition Assembly

Zirconium 26%
Lead Peroxide 71%
Tetracene 3%

(Table III continued on page 29)

Table III (Continued)

16 mg, 10,000 psi
Inert parts and assembly as per LD 479616 except
(1) modify cup by shortening to 0"075,
(2) replace single hole washer with two hole washer: OD - 0"104; thickness - 0"015; hole diameter - 0"020; hole centers - 0"025
Finished: OD - 0"119; length - 0"050
Stop load ignition assembly to 0"045 in assembly

Delay Mix

Zirconium Nickel Alloy 30/70	35%
Lead Peroxide	65%

53 mg; 20,000 psi; 0"042 length

Detonator Explosives

Loaded directly into the delay case against delay mix
85 mg, Polyvinyl Alcohol Lead Azide; 20,000 psi; 0"096 length
54 mg, PETN; 20,000 psi; 0"136 length

Delay Case

As per LD 479616 except
(1) shorten to 0"375 - 0"005,
(2) ream to 0"136 ID.
Finished: OD - 0"160; length - 0"351

Test Rounds 106 - 125
Increased Diameter Base Charge Assembly
Entire Support by Delay Column

See Figure 8.

Ignition Assembly

Zirconium	26%
Lead Peroxide	71%
Tetracene	3%

16 mg; 10,000 psi
Inert parts and assembly as per LD 479616 except
(1) modify cup by shortening to 0"075,
(2) replace single hole washer with two hole washer: OD - 0"104; thickness - 0"015;

(Table III continued on page 30)

Table III (Continued)

hole diameter - 0"020; hole center- 0"025
Finished: OD - 0"119; length - 0"050
Stop load ignition assembly to 0"045 in assembly

Delay Mix

Zirconium Nickel Alloy 30/70	35%
Lead Peroxide	65%

53 mg; 20,000 psi; 0"042 length

Base Charge Assembly

78 mg, Polyvinyl Alcohol Lead Azide; 10,000 psi; 0"116 length
38 mg, PETN; 10,000 psi; 0"123 length
Starting Cup (aluminum): wall - 0"005, length - 0"275 + 0"005; OD - 0"133 - 0"001; ID - 0"123 + 0"001
Paper Disc: OD - 0"120; thickness - 0"002
Finished: OD - 0"135; length - 0"249
In assembly stop load to 0"020 shrinkage

Delay Case

As per LD 479616 except
(1) shorten to 0"375 - 0"005,
(2) ream to 0"136 ID.
Closing Disc - 0"134 OD x 0"005 thick stainless steel
Finished: OD - 0"160; length - 0"351

Test Rounds 126 - 140
(Rounds 136 - 140 not fired)
Stab Detonator

Design not illustrated

This is a conventional stab detonator designed to fill all available space in the rotor cavity. Details follow:

Starting Cup
Material: Stainless Steel; OD - 0"160; ID - 0"140; length - 0"475
Input Disc
Material: Stainless Steel; OD - 0"137 thickness - 0"001
Output Disc
Material: Stainless Steel; OD - 0"137; thickness - 0"005
Charge
47 mg NOL #130 priming mix, 30,000 psi, 0"058 length
2 x 75 mg, Lead Azide; 10,000 psi; 0"212 length
64 mg, Tetryl; 10,000 psi; 0"145 length
Finished: OD - 0"160; length - 0"435

Table III (Continued)
Increased Diameter Base Charge
Directly Loaded Explosive
Test Rounds 141 - 160

Not illustrated, but essentially that shown in Figure 7 except for the interposition of a cushioning plastic washer between the delay and lead azide increments.

Ignition Assembly

Same rounds 86 - 105, except, use slotted washer:
OD - 0".104; thickness - 0".015
Slot - 0".050 x 0".020

Delay Mix

Same rounds 86 - 105
Followed by one polyethylene washer, rounds 141 - 150; two polyethylene washers, rounds 151 - 160.
Polyethylene Washer: OD - 0".138; thickness - 0".004; hole - 0".081 diameter
Followed by Paper Disc: OD - 0".104; thickness - 0".002

Detonator Explosive

Same rounds 86 - 95

Delay Case

As per LD 479616 except
(1) shorten to 0".375 - 0".005,
(2) ream to 0".136 ID
Closing Disc: 0".134 OD x 0".005 thick stainless steel
Finished: OD - 0".160; length - 0".351

Table IV

FIELD TEST RESULTS
DELAY DETONATOR, ARMY STARTING DESIGN
(Figure 5)

Test Rounds 1 - 50

Test Round No.	Field Evidence		Photographic Evidence	
	Delay Inches	Explosive Order	Delay Inches	Explosive Order
1	12-18	H	3	H
2	Dud	-	Dud	-
3	6-12	H	3	H
4	6-12	H	- - No film - -	
5	24-36	L	3	L
6	24-30	H	21	H
7	18-24	H	2	H
8	6-12	H	2	H
9	36	L	3	L
10	6-12	H	4	H
11	48	L	6	L
12	36-48	H	3	H
13	36-48	L	9	L
14	6-12	H	6	H
15	24-36	L	3	L
16	6-12	H	2	H
17	36-48	L	8	L
18	180-240	L	Dud	-
19	Dud	-	12	L
20	Dud	-	38	L
21	60-72	L	6	L
22	84-96	L	48	L
23	12-18	H	3	H
24	6-12	H	4	H
25	96-120	L	Dud	-
26	12-18	H	6	H
27	6-12	H	3	H
28	0-6	H	1	H
29	36-48	L	12	L
30	84-96	L	6	L
31	Dud	-	Dud	-
32	36-48	L	4	L

(Table IV continued on page 33)

Table IV (Continued)

Test Round No.	Field Evidence		Photographic Evidence	
	Delay Inches	Explosive Order	Delay Inches	Explosive Order
33	12-18	H	9	H
34	84-96	L	12	L
35	6-12	H	6	H
36	6-12	H	4	H
37	6-12	H	2	H
38	Dud	-	Dud	-
39	0-6	H	2	H
40	6-12	H	2	H
41	48-60	L	8	L
42	72-84	L	6	L
43	6-12	H	6	H
44	6-12	H	- - No film - -	
45	6-12	H	6	H
46	ND	H	ND	H
47	Dud	Dud	- - No film - -	
48	ND	H	ND	H
49	6-12	H	8	H
50	24-36	H	27	H

The Delay Detonator assembly details are contained in Table III, Rounds 1 - 50.
Delay = Distance (inches) behind target for explosive bursts.
H = High Order; L = Low Order; ND = No Delay (on target fire)

Test Conditions:

Average Projectile Velocity - 2750 ft/sec.
Projectile Path - Parallel to and approximately 18-inches above ground.
Projectile-Target Obliquity - 0°
Gun-Target Distance - 100 feet
Target-Backstop Distance - 40 feet, approximately
Target - 1/4-inch aluminum (24 ST)
Target Hole Rounds 28,39 - 2 inch
Target Hole Rounds 46,48 - 6 to 7 inch
Target Hole All Others - 1-1/4 inch (one caliber)

(Table IV continued on page 34)

Table IV (Continued)

Delay Time
Bench Test Control
TN = 30 (2, long delay; 1, timer fail)
N = 27
$\overline{X}$ = 309 Microseconds Delay
S = 109

TN = Total Trials
N = Number of Trials Applying to $\overline{X}$ & S Values
$\overline{X}$ = Mean, S = Standard Deviation

TABLE V

OUTPUT RESULTS FOR VARIOUS BASE CHARGE ASSEMBLIES TESTED AS SHOWN IN FIGURE 2

ITEM #	CUP MATERIAL WALL THICKNESS (INCH)	CHARGE DIAMETER (INCH)	LOADING PRESSURE (PSI X 10-3)	LEAD AZIDE TYPE CHARGE (MG)	LEAD AZIDE LENGTH (INCH)	HE TYPE CHARGE (MG)	HE LENGTH (INCH)	TEST SLEEVE MATERIAL WALL THICKNESS (INCH)	OUTPUT RESULTS DENT (INCH X 10³) N	$\bar{X}$	S	CV %
1	AL 0.005	0.108	10	PVA 60	0.114	PETN 28	0.122	S STL 0.020	20	14.6	0.6	5
2	AL 0.005	0.108	10	PVA 30	0.057	PETN 43	0.179	S STL 0.020	10	15.4	0.8	5
3	AL 0.005	0.108	10	PVA 90	0.176	PETN 15	0.062	S STL 0.020	10	13.2	0.3	3
4	AL 0.005	0.108	20	PVA 90	0.163	PETN 19	0.074	S STL 0.020	10	14.8	0.5	3
5	AL 0.005	0.108	20	PVA 64	0.114	PETN 31	0.122	S STL 0.020	10	15.7	0.5	3
6	AL 0.005	0.108	10	AGN3 39	0.069	HMX 42	0.167	S STL 0.020	10	17.9	0.7	4
7	AL 0.005	0.108	10	AGN3 20	0.034	HMX 51	0.203	S STL 0.020	7	17.0	0.7	4
8	AL 0.005	0.108	10	AGN3 39	0.069	HMX 42	0.167	CR STL 0.060	15	19.8	1.5	7
9	AL 0.005	0.108	10	AGN3 20	0.034	HMX 51	0.203	CR STL 0.060	14	22.2	1.5	7
10	AL 0.005	0.108	10	AGN3 39	0.069	HMX 42	0.167	CR STL 0.060	15	19.3	0.8	4
11	AL 0.005	0.108	10	AGN3 64	0.114	HMX 31	0.122	CR STL 0.060	10	20.4	1.2	6
12	AL 0.005	0.108	10	PVA 60	0.114	PETN 28	0.122	CR STL 0.060	15	16.8	1.1	7
13	AL 0.005	0.124	10	PVA 78	0.116	PETN 38	0.123	CR STL 0.052	25	18.2	0.9	5
14	AL 0.005	0.124	10	PVA 51	0.076	PETN 50	0.162	CR STL 0.052	25	18.7	1.4	8
15	S STL 0.010	0.140	10	DEX 150	0.212	TETRYL 64	0.145	PLASTIC	10	18.9	0.3	2
16	S STL 0.010	0.140	10	DEX 150	0.212	TETRYL 64	0.145	CR STL 0.054	10	24.9	1.1	4
17	AL 0.005	0.108	10	PVA 60	0.114	PETN 28	0.122	CR STL 0.060	10	16.7	1.0	6

(Notes in reference to Table 5 on following page.)

TABLE V (Continued)

NOTES

HE = High Explosive
AL = Aluminum
PVA = Polyvinyl Alcohol Lead Azide
S STL = Stainless Steel
AGN3 = Silver Azide
CR STL = Cold Rolled Steel
DEX = Dextrinated Lead Azide
N = Number of Trials
$\bar{X}$ = Mean Dent
S = Standard Deviation
CV = S / $\bar{X}$ x 100 (%)

Items 1 - 7 = Improvised Igniter Plug and Test Sleeve
Items 8 - 17 = Standardized Igniter Plug and Test Sleeve
Items 6 - 10 = Old Lot Silver Azide (X-117)
Items 14 and 15 = New Lot Silver Azide (X-201)
Item 9 = One low order
Items 15 and 16 = Conventional Stab Detonator, Details are shown in TABLE III (126 - 140)
Items 1, 12, 17 = Identical; Used in Army Starting Design shown in Figure 5
Item 13 = Used in Designs shown in Figures 6 and 8

Table VI

OUTPUT RESULTS FOR VARIOUS DELAY DETONATOR DESIGNS TESTED AS SHOWN IN FIGURE 3

Item #	Lead Azide		HE		OUTPUT RESULTS DENT, Inch x 10^3				Low Orders
	Type	Charge Mg	Type	Charge Mg	N	$\overline{X}$	S	CV,%	
1	PVA	60	PETN	28	10	29.6	1.7	6	0
2	PVA	60	PETN	28	10	28.2	2.0	7	0
3	AGN3	39	HMX	42	5	31.2	1.8	6	5/10
4	AGN3	64	HMX	31	8	32.5	1.7	5	3/11
5	AGN3	64	HMX	31	10	32.5	1.4	4	0
6	PVA	78	PETN	38	10	35.2	1.6	5	0
7	PVA	85	PETN	54	10	37.6	1.5	4	0
8	DEX	150	Tetryl	64	10	36.8	2.2	6	0

Item 1: Army starting design, shown in Figure 5.
Item 2: Identical to item 1 except a Picatinny booster was used in test assembly to provide NOL-PA booster comparison data; Picatinny boosters could not be supplied in time and therefore NOL CH-6 boosters were used in all other tests and in all field tests.
Items 3 and 4: Old lot of silver azide (X-117).
Item 5: Identical to item 4 except new lot of silver azide, (X-201) was used.
Item 6: Design shown in Figure 6, and Figure 8.
Item 7: Design shown in Figure 7.
Item 8: Conventional stab detonator.

HE = High Explosive.
PVA = Polyvinyl Alcohol Lead Azide.
AGN3 = Silver Azide
N = Number of Trials
$\overline{X}$ = Mean
S = Standard Deviation
CV = S/$\overline{X}$ x 100 (%)

Table VII

FIELD TEST RESULTS
FIGURE 7 DESIGN (Test Rounds 86 - 95)
FIGURE 8 DESIGN (Test Rounds 106 - 125)
STAB DETONATOR (Test Rounds 126 - 135)

Test Round No.	Target Hole Inches	Delay Inches	Explosive Order
86	1-1/4	3	H
87	4-1/2	ND	H
88	2	0-1	H
89	3-1/2	ND	H
90	1-1/4	4	H
91	6	ND	H
92	6	ND	H
93	2-1/4	0-1	H
94	1-7/8	0-1	H
95	5	ND	H
106	?	?	H
107	1-1/4	2	H
108	1-1/4	2	H
109	1-1/4	1	H
110	1-3/4	0-1	H
111	1-1/2	0-1	H
112	1-1/4	42	H
113	1-1/4	9	H
114	- - Target Miss - - -		
115	1-1/4	74	H
116	1-1/4	4	H
117	1-1/4	74	H
118	1-1/4	62	H
119	1-1/4	7	H
120	1-1/4	124	H
121	1-1/4	5	H
122	- - Target Miss - - -		
123	1-1/4	2	H
124	1-1/4	3	H
125	1-1/4	3	H

Table VII continued on page 39.

Table VII (Continued)

Test Round No.	Target Hole Inches	Delay Inches	Explosive Order
126	8	ND	H
127	6	ND	H
128	6	ND	H
129	6	ND	H
130	6	ND	H
131	6	ND	H
132	1-1/4	8	H
133	1-1/4	6	H
134	8	ND	H
135	8	ND	H

(Table VII continued on Page 40)

Table VII (Continued)

The assembly details of the items tested are contained in Table III.
Rounds 96 to 105 and 136 to 140 were prepared but were not fired.
H = High Order
ND = No Delay

<u>Test Conditions:</u>

Average Projectile Muzzle Velocity - 2750 ft/sec.
Projectile Path - Parallel to and about 36 inches above the ground.
Projectile - Target Obliquity - 0°
Gun - Target Distance - 300 feet
Target Backstop Distance - 121 feet
Targets - 1/4-inch aluminum (24 ST)
3/64-inch aluminum (24 ST)
1/8-inch cardboard
3/4-inch celotex

Round 86 - Missed aluminum target, passed through wooden frame.
Round 87 - No film record, data on basis of target hole and witness screens.
Round 106 - Top witness screen blown off a storage pile against target just before fire.
Rounds 111 and 112 - Color film used; were under exposed but two light flashes perceptible; assumed to be plate flash and explosive burst; delay estimated on this basis.
Rounds 115, 117, 118, 120 - Burst beyond witness screen; delay estimated on basis of fragmentation pattern on ground; patterns were distinct, therefore feel estimate is accurate.
Rounds 117 and 118 - Target material, 3/4-inch celotex board.
Rounds 132 and 133 - Target material, 1/8-inch cardboard
Rounds 134 and 135 - Target material, 3/64-inch aluminum (24 ST)

Delay Time
Bench Test Control
Rounds 86 - 95
$N = 13$
$\bar{X} = 240$ microseconds
$S = 64$
CV = 27%

Delay Time
Bench Test Control
Rounds 106 - 125
TN = 10 (1 long delay)
$N = 9$
$\bar{X} = 363$ microseconds
$S = 86$
CV = 24%

Table VIII

FIELD TEST RESULTS
FIGURE 7 DESIGN, MODIFIED
Test Rounds 141 - 160

Round Number	Target Hole Inches	Delay Inches	Explosive Order
141	1-1/4	0-6	H
142	1-1/4	0-6	H
143	5	ND	H
144	4-1/2	ND	H
145	4	ND	H
146	4	ND	H
147	4	ND	H
148	1-1/4	0-6	H
149	1-1/4	0-6	H
150	1-1/4	0-6	H
151	4	ND	H
152	1-1/4	0-6	H
153	6	ND	H
154	1-1/4	0-6	H
155	1-3/4	0-6	H
156	- - Target Miss - - -		
157	- - Target Miss - - -		
158	4-1/2	ND	H
159	4	ND	H
160	3-1/2	ND	H

Table VIII Continued on page 42.

Table VIII (Continued)

The assembly details of the delay detonators tested are contained in Table III.

The high speed photographic technique was not employed in this test. The witness screen was the basis for judgment. This information is considered reliable as the fragmentation patterns were distinct and typical of high orders.

Test Conditions

Average Projectile Muzzle Velocity - 2750 ft/sec.
Projectile Path - Parallel to and 18 to 36 inches above the ground
Projectile-Target Obliquity - 0°
Gun-Target Distance - 300 feet
Target-Backstop Distance - 23 feet
Target Material - 1/4-inch aluminum (24 ST)

Rounds 141 - 150 - one polyethylene washer used between delay and lead azide increments
Rounds 151 - 160 - two polyethylene washers similarly used
Round 154 - Round passed through both the 1/4-inch aluminum target and a 3/8-inch angle iron support. Target holes for both were 1-1/4 inches.

Delay Time, Bench Test Control

	One Washer Rounds 141 - 150	Two Washers Rounds 151 - 160
N	10	10
$\bar{X}$	288 microseconds	346 microseconds
S	78	81
CV	27%	23%

Table IX

FIELD TEST RESULTS
PHOTOGRAPHIC STANDARDS (Rounds 51 - 75)
FIGURE 6 DESIGN (Rounds 76 - 85)

Round No.	Film	Witness Screen 1	Witness Screen 2	Target Hole Inches	Photo Delay Inches	Explosive Order	Explosive Train Makeup
None	*	-	-	1-1/4	-	-	Inert, equipment test round
51	*	*	*	1-1/4	-	-	
52	*	-	-	"	-	-	Live through
53	*	*	*	"	-	-	delay detonator;
54	*	*	*	"	-	-	Rest inert
55	*	*	*	"	-	-	
56	*	*	*	"	-	-	
57	*	*	*	"	-	-	Live through
58	*	*	*	"	-	-	booster; rest
59	*	*	*	"	-	-	inert
60	*	*	*	"	-	-	
61 T	*	-	-	"	-	-	
62 T	*	*	*	"	-	-	Live through
63 T	*	*	*	"	-	-	projectile
64 T	*	*	*	"	-	-	pellet;HE
65 T	*	*	*	"	-	-	inert
66 T	*	*	*	"	1	H	
67 T	*	*	*	"	2	L	100% Live
68	-	-	-	"	-	-	
69 T	*	*	*	"	1	H	
70	-	*	*	"	(2)	(H)	
71	-	-	-	-	-	-	
72	-	-	-	-	-	-	Live through
73	-	-	-	-	-	-	primer;
74	-	-	-	-	-	-	Rest inert
75	-	*	*	1-1/4	-	-	

Table IX Continued on page 44.

Table IX (Continued)

Round No.	Film	Witness Screen 1	Witness Screen 2	Target Hole Inches	Photo Delay Inches	Explosive Order	Explosive Train Makeup
76	*	*	*	1-1/4	6	H	
77	*	*	-	3-1/8	ND	H?	
78	*	*	*	1-1/4	1	H	
79	*	*	*	3-1/8	ND	H	Figure 6
80	*	*	*	1-1/4	2	H	Design
81	-	-	-	1-1/4	Dud	Dud	
82 T	*	-	-	1-1/4	Dud	Dud	
83 T	*	*	*	4-3/4	ND	H	
84 T	*	*	*	4-3/4	ND	H	
85 T	*	*	*	1-1/4	2	H	

NOTES:

The assembly details of the items tested are contained in Table III.

* = Photographic high speed film record or photographs of witness screens were obtained.
T = Telephoto lens used.
H = High Order
L = Low Order
ND = No Delay

Test Conditions

Average Projectile Velocity - 2750 ft/sec.
Projectile Path - Parallel to and approximately 18 inches above ground
Projectile-Target Obliquity - 0°
Gun-Target Distance - 310 feet
Target-Backstop Distance - 40 feet approximately
Target - 1/4-inch aluminum (24 ST)

Round 70 - Delay and order estimated basis witness screen
Round 77 - Best judgment, probable high order

(Table IX continued on page 45.)

Table IX (Continued)

Delay Time
Bench Test Control
Rounds 76 - 85
TN = 20 (2 long delays)
$\underline{N}$ = 18
$\overline{X}$ = 388
s = 60
CV = 15%

Table X

SUMMARY OF RESULTS ON RUPTURED CASE STUDY

Item #	Igniter Mix	Charge mg	Washer Design	Delay Case	Stab Primer	Delay Time, Microseconds TN	N	$\bar{X}$	S	CV%	
1	1	29	1	2	1	14	13	425	119	28	1xIN
2	1	29	1	2	1	11	11	357	63	18	
3	1	29	1	2	1	25	24	342	101	30	1xRC
4	1	15	1	2	1	26	25	747	243	33	1xCI
5	1	23	1	3	1	25	18	427	152	36	3xRC;4xLT
6	1	29	1	4	1	25	13	528	174	33	7xRC;5xLT
7	1	15	2	2	1	25	23	697	269	39	2xLT
8	1	15	2	4	1	24	22	809	444	55	1xCI
9	1	15	1	4	1	25	15	541	167	31	5xRC;5xLT
10	1	23	1	1	2	15	13	454	219	48	1xLT;1xIN
11	1	23	1	3	2	15	14	322	63	22	1xLT
12	2	23	1	1	2	15	15	280	62	22	
13	2	23	1	3	2	15	8	349	78	22	4xRC;3xLT
14	2	28	1	2	1	15	14	268	64	24	1xLT
15	2	28	1	4	2	15	2 fires				13xRC;2xLT
16	2	28	1	2	2	15	7	313			3xRC;5xLT
17	2	15	2	2	1	15	13	295	102	35	2xIN

IN = Instrument troubles
RC = Ruptured case
LT = Long time
CI = Case intact (complete fail)

(Table X continued on page 44.)

Table X (Continued)

Igniter Mix Compositions

Component:	Mix 1:	Mix 2:
Zirconium	26%	24.3%
Lead Peroxide	71%	65.7%
Tetrecene	3%	5.0%
Basic Lead Styphnate	-	5.0%

Washer

1 = BuOrd dwg 1620852
2 = same, except 0".020 eccentric hole
0".020 off center

Delay Case

1 = BuOrd dwg 1620849
2 = Same but anvil milled off
3 = same 1, thin top by 0".005
4 = same 1, mill anvil and thin top by 0".005

Stab Primer

1 = Buord dwg 1553605
20 mg Lead Azide
2 = 30 mg Lead Azide

Finished Length of Igniter

4, 7, 8, 9, 17 = 0".046
All others = 0".061

Table XI

EFFECT OF WASHER DESIGN ON
IGNITER CHARACTERISTICS

Item #	Washer	TN	N	$\bar{X}$	S	CV,%	
1	Standard	15	14	281	76	27	1xLT
2	2 x 0"020	15	15	272	49	18	--
3	3 x 0"020	15	13	324	54	17	2xLT
4	4 x 0"020	15	14	321	72	22	1xLT
5	1 x 0"035	15	14	261	45	17	1xLT
6	Slot (0"020 x 0"050)	15	14	272	67	25	1xIN
7	Solid Disc	15	- - All fail or long delay time - -				

LT = Long delay time
IN = Instrument trouble
TN = Total trials

Figure 5 was the basic design used. The only variable was washer design. The design change was the number and dimensions of the holes. The standard washer had 1 hole, 0"026 diameter.

Item 7: 5 fail, case top bulged but not split
5 fail, case top split open
5 long delay time, min = 20,000 microseconds

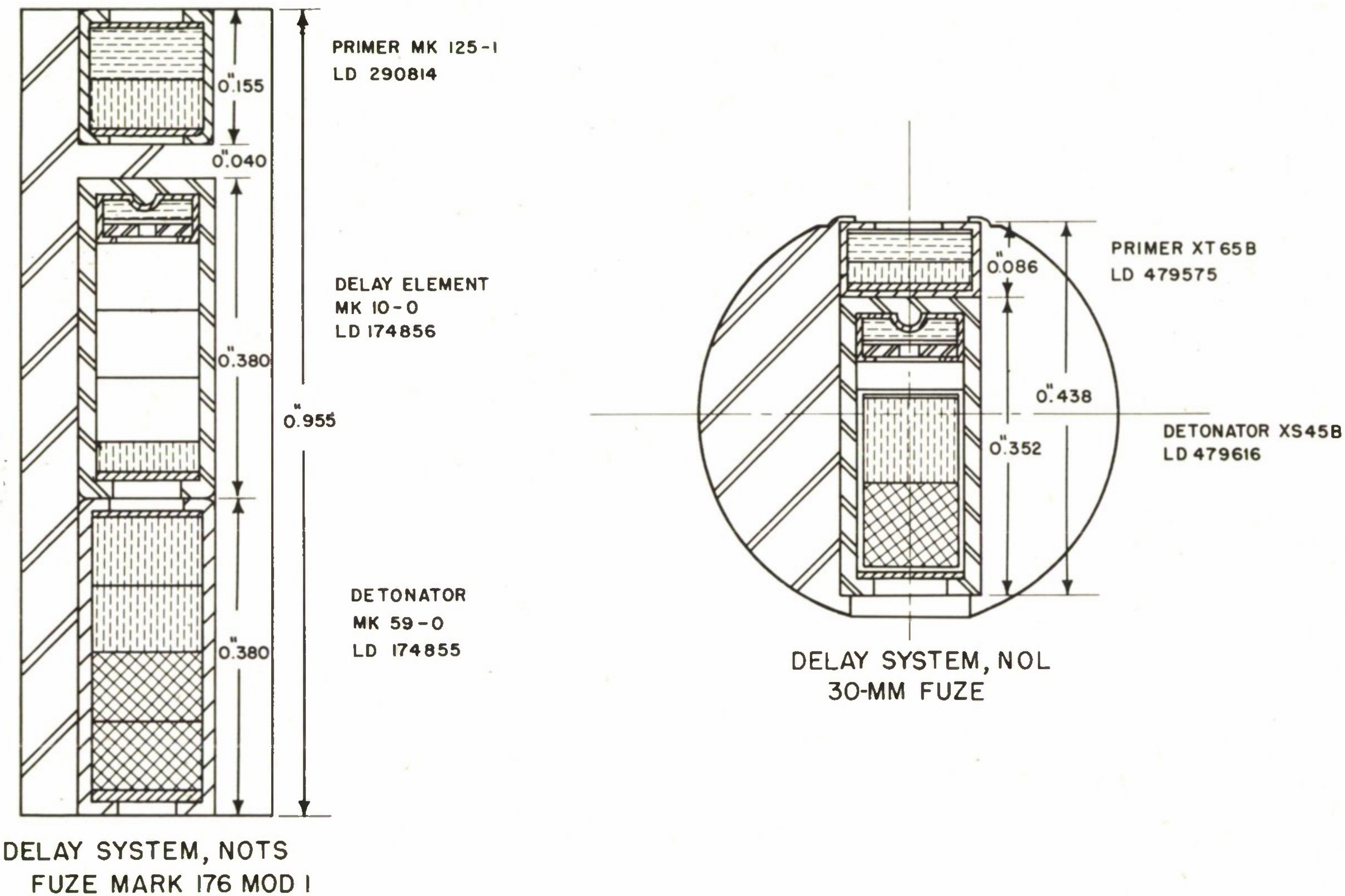

FIG. 1 DEVELOPMENT STATUS OF NOL DELAY - DETONATOR SYSTEM AT START OF ARMY PROGRAM SHOWING DERIVATION OF NOL SYSTEM FROM NOTS SYSTEM

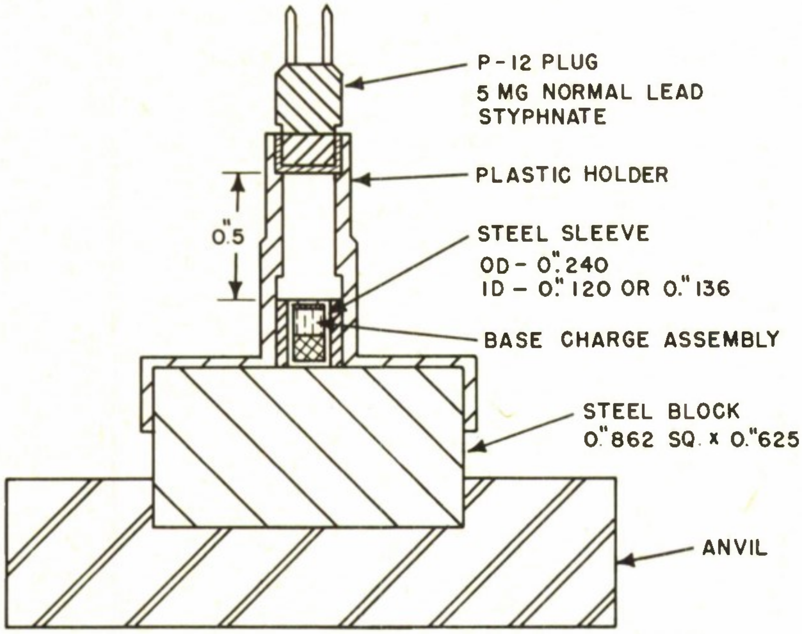

FIG. 2 STEEL BLOCK DENT TEST, BASE CHARGE ASSEMBLY, OUTPUT TEST

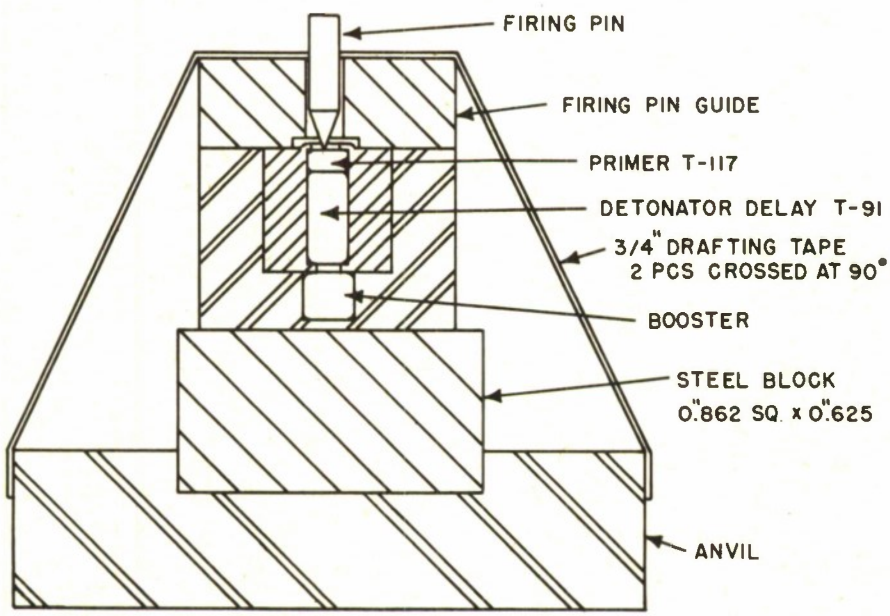

FIG. 3 STEEL BLOCK DENT TEST SIMULATED 30 MM FUZE, OUTPUT TEST ASSEMBLY

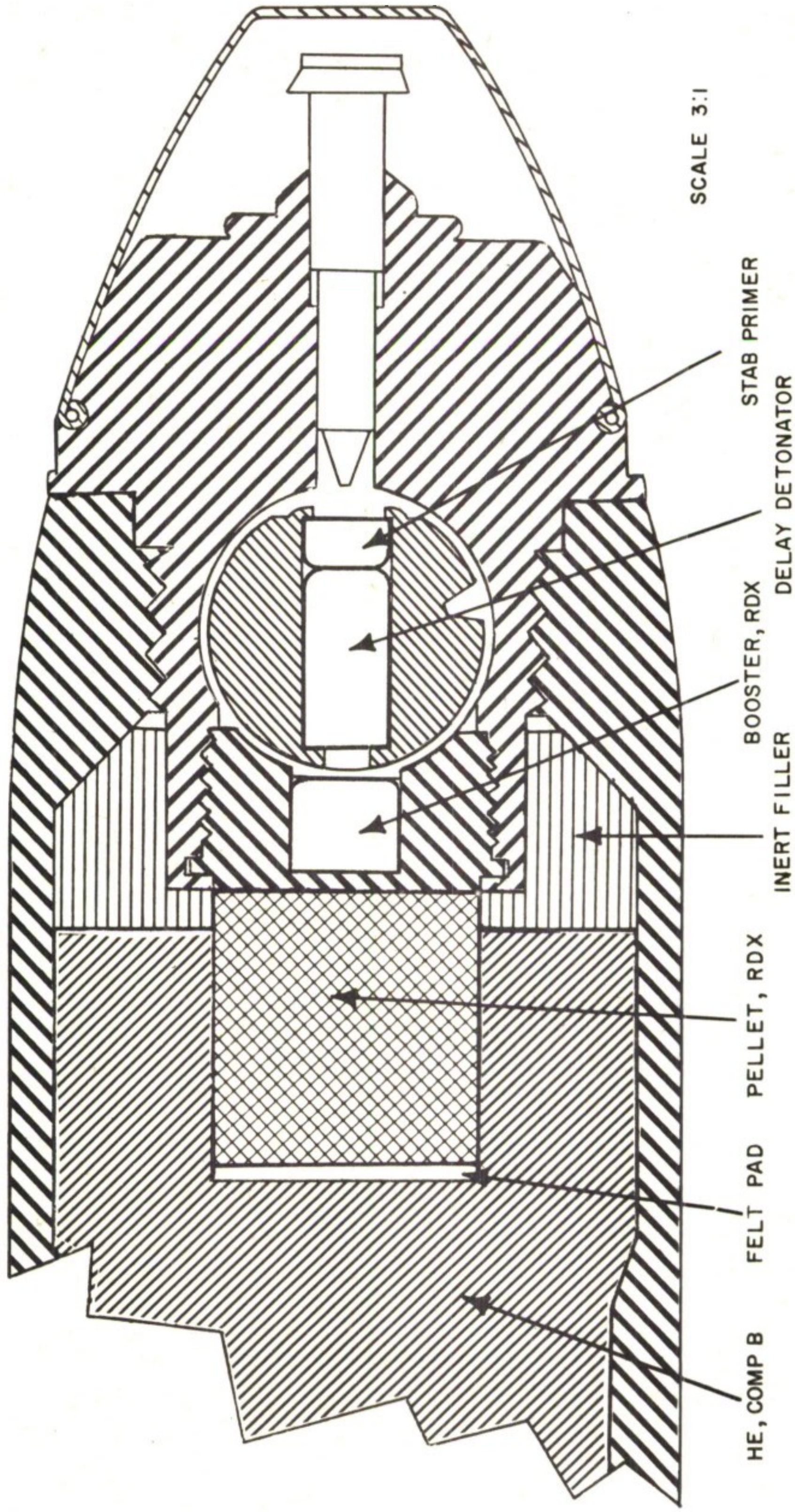

FIG. 4 EXPLOSIVE TRAIN SCHEMATIC, 30-MM TEST PROJECTILE

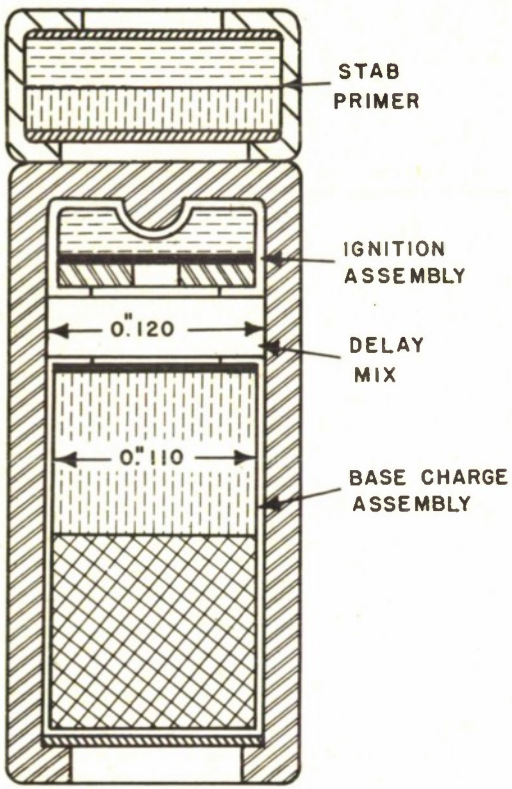

FIG. 5 (STARTING DESIGN)

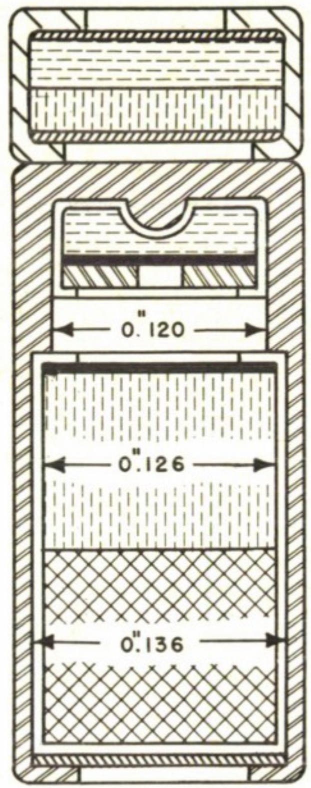

FIG. 6

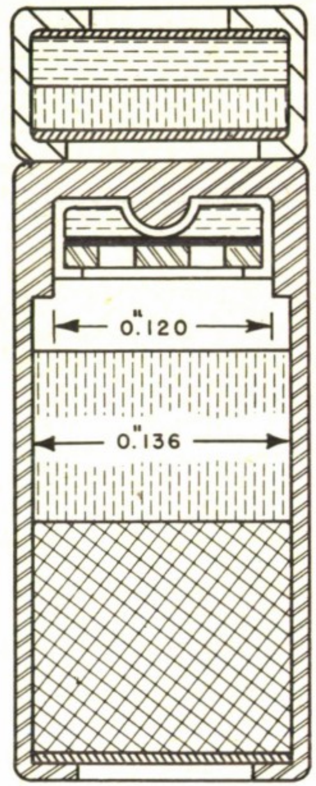

FIG. 7

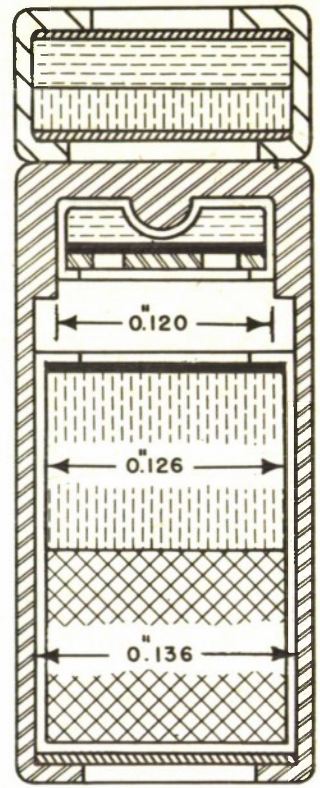

FIG. 8

VARIOUS DELAY-DETONATOR DESIGNS DEVELOPED TO INCREASE OUTPUT

SEE TABLE III FOR ASSEMBLY DETAILS

APPENDIX I

SUPPLEMENTARY FIELD TEST DATA

The results of some field tests omitted from the text are treated below. This includes tests devised to establish photographic standards, oddments to amplify this data, and tests in which stab detonators were used.

__Photographic Standards__

The lack of complete agreement by different observers in analyzing high speed film particularly in determining magnitude of order suggested the need for photographic standards. Toward this end tests were designed in which components of the train of the test projectile shown in __Figure 4__ were successively inert loaded. Both the high speed camera and witness screens were employed in these tests. Two witness screens were used to increase the probability of recording the fragmentation patterns. It was hoped that records obtained of high speed film and witness screens might prove helpful in the interpretation of field test results. Assembly details are shown in __Table III__, rounds 51 through 75 and field data in __Table IX,__ rounds 51 through 75.

__High Speed Film__. Unfortunately, very bad weather conditions at the time of the test played havoc with the instrumentation and photographic efforts. Some runs were lost and the quality of most of the film was poor. This made judgment in most instances difficult, and in some, impossible. Although the results of the tests were of some value, they certainly did not provide anything approaching absolute standards for determining order of explosion. The best that could be obtained from study of the film is that:

> The plate flash from the inert instrument test round appeared as a ball of light about six inches in diameter about six inches behind the target and was evident still when the projectile passed out of the field. This plate flash effect derives from projectile and aluminum target impact and is present for all rounds of whatever makeup where an aluminum target is used.

Appendix I (Continued)

No film was obtained for the live primer-rest inert group. The film records for the live through delay group and the live through booster group were essentially the same as the inert instrument check round. If any explosive activity were present it was masked by the plate flash. A test using a nonmetallic target like cardboard might clear up this point. A best guess is that there were no explosive effects recorded on the film.

Distinctive explosive activity was first noticed in the group assembled live through projectile pellet, and these rounds show considerable variation. In general, high order detonations for the live through projectile pellet group can be distinguished from the 100 percent live group by the greater explosive activity evidenced in the latter.

Witness Screens. As regards witness screens, the inert instrument check round, the live through primer group (one trial) and the live through booster group are essentially identical. The first difference appears in the live through projectile pellet group, in which the distinctive features are black smears on the Number 1 witness screen and a greater number and larger holes in the Number 2 witness screen. This confirmed the results obtained with high speed film. In general, for high order detonations, the 100 percent live group could be distinguished from the live through pellet group, by the Number 1 witness screen which contained the horizontal peppered band typical of high orders. This band was not present in the live through pellet group.

Use of Telephoto Lens. A telephoto lens was used for several rounds. The film for these rounds showed greater detail, but a decreased field and a smaller bit of the event. Consequently, the telephoto lens would be of value only for those rounds firing within a few feet behind the target.

Color Film. Kodachrome color film was used for rounds 111 - 112, Table VII. Unfortunately, the film was very much under exposed. Only two light splotches were perceivable on the film. They were interpreted as plate flash and first explosion and the difference between them as the delay distance.

Appendix I (Continued)

Perhaps faster color films would make full exposure possible, then color film might be quite helpful in sorting out explosive effects particularly magnitude of order.

Celotex Targets

Rounds 117 - 118, Table VII, were fired against celotex targets 3/4-inch thick. The primary interest in this case was film data on explosive effects unmasked by plate flash. This was a problem in the photographic standard series in which an aluminum target was used. Unhappily both rounds were long delays, 74 and 62 inches, and explosion occurred beyond the camera field. The "plate flash" appearance on film was a puff of whispy gray smoke, entirely different from the distinctive while ball in the case of an aluminum target.

Two successive long delays on the celotex target seemed odd despite the fact that normal long delays are inherently possible in the system. Also to be considered is the fact that stab detonators, when fired against relatively hard cardboard, showed 7-inch delays. This would indicate a delay deriving entirely from target impact effects. Thus the 7-inch delay with an instantaneous detonator might arise because of the longer time involved for the firing pin to move into the priming mix and start chemical action. In the case of the softer celotex target, this time might be longer still. This conjecture poses questions as to the validity of designating the celotex rounds normal long delays. These questions could only be resolved by further testing to determine if consistent initiation were possible on celotex targets, and if so how much of the delay can be attributed to target alone.

Stab Detonators

Rounds 126 - 135, Table VII, contained stab detonators. The stab detonator filled the entire rotor cavity and represented the upper output limit. Of interest was the appearance on film of such a fire and also the frequency of high orders.

Appendix I (Continued)

Rounds 126 - 131 were all high order detonations on the basis of witness screen interpretation. They were all no delays. The target hole was quite large, 6 to 8 inches. This established a standard for target hole sizes for the case of no delay. The film for these rounds was obscured by the high intensity light from the plate flash.

Because of the blast effect with no delay fires, rounds 126 - 131 were blown off the frame and in one or two cases the entire framework supporting the target and reference board was knocked down. For this reason, and because of a natural curiosity concerning sensitivity, two rounds were fired against a 1/8-inch cardboard target with the hope that the cardboard would pull away and leave the frame intact. Surprisingly, the target holes were 1-1/4 inches, indicating a delay. Film examination showed delays of 8 and 6 inches. The explanation for a delay with a stab detonator is probably a matter of impact being less for cardboard than aluminum and time involved in firing pin initiation. These rounds provided photographic standards unmasked by metallic plate flash for a known delay and a known high order.

A target material, 3/64-inch aluminum, heavier than cardboard but appreciably lighter than 1/4-inch aluminum was selected for use in rounds 134 - 135. Here obvious no delays were obtained, the target holes being 8 inches.

Although it was not the original intent, some small information was obtained on the effect of different target materials on the delay for stab detonators. No delays resulted in the case of 1/4-inch and 3/64-inch aluminum, but delays of about 7 inches resulted in the case of 1/8-inch cardboard. These effects with stab detonators would be superimposed on the delay detonator as initiation by firing pin action is the same for both.

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Commander Wright Air Development Center Wright-Patterson Air Force Base Dayton, Ohio	1
Universal Match Corporation Marion, Illinois (NOrd 13466)	1